The Effect of Shadowing on Initial Conditions, Transverse Energy and Hard Probes in Ultrarelativistic Heavy Ion Collisions*

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The modification of nucleon structure functions in nuclei, a depletion at small and medium x and an enhancement at intermediate x, is well established in nuclear deep-inelastic scattering. However, the source of the modification, or shadowing, is not completely understood. Two primary models are recombination of long wavelength partons and multiple interactions of the incoming parton along the path length through the nucleus.

Shadowing should depend on the location of the parton in the nucleus since partons in nucleons closer to the nuclear surface should be less shadowed because there is a lower probability to either recombine with partons in neighboring nucleons or to be part of a multiple interaction chain. We have studied two spatial parameterizations of shadowing, one proportional to the local nuclear density and the other to the path length through the nucleus. Both are normalized so that an integration over the nuclear volume reproduces the spatial average results reported in nuclear deep-inelastic scattering. The impact parameter dependence is stronger than the average in central collisions and disappears as $b \to \infty$.

Because no model of shadowing can explain the effect over all x, we use three parameterizations of nuclear shadowing to explore the its effects on the initial conditions at RHIC and LHC. Unfortunately, the nuclear gluon distribution is least constrained by data and most important for particle production in hard interactions. The behavior of the gluon distribution is significantly different in the three parameterizations.

We have calculated minijet production and the corresponding E_T moments at RHIC and LHC energies assuming hard production for $p_T \geq p_0 = 2$ GeV. We use these moments, along with the expected soft component to estimate the effect of shadowing on the initial conditions for further evolution of the hot system created in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV and Pb+Pb collisions at $\sqrt{s_{NN}} = 5.5$ TeV. As expected, at the higher energy, the semihard minijets dominate particle production. The energy and number densities calculated at 5.5 TeV without shadowing result in a ratio ϵ_i/n_i close to that expected for an ideal gas with a temperature of ≈ 1.1 GeV. However, when shadowing is included, this 'temperature' is reduced by $\approx 10\%$ so that $\epsilon_i/n_i > \epsilon_{\rm th}/n_{\rm th} \sim 2.7T_{\rm th}$. At RHIC, minijet production is on the level of the soft particle production so that the hard component is responsible for only $\approx 40\%$ of the particle production. Thus the system is even further from equilibrium. These results are reflected in the total E_T distributions at LHC and RHIC. While the LHC distributions are strongly affected by shadowing, the predominatly soft E_T production at RHIC shows little influence of shadowing.

We also studied the effects of shadowing on the J/ψ, Υ, and Drell-Yan yields. A careful measurement of these rates as a function of rapidity can help distinguish between shadowing models as well as the quarkonium production mechanism. Since the effect of shadowing depends on the Drell-Yan pair mass, if the Drell-Yan yield is to be used as a baseline to compare the yield of other hard probes, the rates should be measured directly in the mass region of interest rather than relying on calculations to extrapolate into an unmeasured region.

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